# DETERMINATION OF ANTHROPOGENIC CHANGES IN URBANIZED TERRITORIES USING GIS TECHNOLOGY

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**Abstract**

The research aim is to obtain a cartographic model of an urbanized territory by means of thermal survey in an infrared range. With this cartographic model, it will be then possible to reduce the zones in the urbanized territories differing in the level of superficial heat. Further, we will be able to reduce the proof thermal anomalies and thermal structures of the localities that are related to the natural and anthropogenic systems. On the examples of the cities of Ukraine – Energodar and Nikopol, we defined the sources of caloradiances from major industrial concerns as well as from thermal and nuclear power plants. For comparison, we built the model of thermal structure of the city of Tokai and the nuclear power plant with the same name Tokai (Japan). The sources of caloradiances can be, for example, pipes of thermal power stations, ponds-coolers, corps of steel-making production, and other similar objects. If the sizes of such source are known, then we are able to get the absolute values of temperatures.

**Key words:** landscape, urban heat island, thermal survey, remote sensing, greenhouse gas

## 1 INTRODUCTION

The artificial environment of a city changes the temperature of the surface of relatively natural landscape. This fact is a reason for geoecological researches of the phenomenon of "urban heat island" in a municipal environment. First the term "urban heat island" was set forth by the British chemist-druggist and meteorologist Luke Howard in 1810 [1]. Today for research of this phenomenon, materials from the thermal survey of space satellites are used.

The first data of space thermal survey were got yet at the beginning of 1960th by touch-controls of the American satellites of TIROS. These data had a low spatial resolution. However, they showed a fundamental possibility to use thermal survey in remote sensing.

Thermal survey is a very perspective technology. Firstly, the data of thermal satellite survey become more easily accessible. For example, it is possible to get thermal images from the United States Geological Survey (USGS). They are in open access on the web-site http://www.glovis.usgs.gov/. These images are executed by the touch-control of TIRS of the Landsat 8 satellite. Secondly, the spatial resolution of the satellite thermal survey increased in several times. The resolution of the first satellite images was several kilometres. While today the resolution of satellite images (for example, Landsat 8) is less than 100 meters. Thirdly, last years the opportunity has occurred to do thermal survey by means of pilotless aircrafts.

## 2 CHARACTERIZATION OF TAR DEPOSITS

A temperature increase in a municipal territory influences the increase of the use of energy and vice versa [1]. For the matter of that, the research was conducted aimed at improving betweenness of the quality of municipal life and the speed of natural resource depletion [2]. In researches [3, 4], it is shown that it is necessary to provide an increase of economy without increasing the environmental burden. Another way is to provide such level of economy to be able to support the increase in gross internal product without increasing the burden on the environment. Moreover, it is necessary to take into account the effect of feed-back, for example, between the increase of economy and losses related to the change of climate [4].

The most important element of the chart (Fig. 1) is a radiation balance. This element is influenced by anthropogenic and natural factors. The most significant factor is an increase in concentrations of greenhouse gases, foremost, CO2. As for natural processes of a rise in temperature, the increase of sunny activity causes an anxiety. A very meaningful factor is the influence of aerosols of anthropogenic origin on the temperature of the surface of techno-geosystem. As indicated in [4], the contamination of the atmosphere with particulates promotes temperature most considerably.

On the chart of feed-back (Fig. 1), a decline in ability of the environment to take in ⟦CO⟧_2 is the most closely-coupled interface. It conduces to the rise in emissions of methane that passes to the ionic forms of HCO3 and CO3. The balance between them depends on the temperature of the atmosphere, acidity of water (pH) and the range of other factors [3]. The dynamics of anthropogenic emissions of greenhouse gases in the atmosphere is the main factor determining the temperature and further consequences of the global warming [4] in the 21st century.

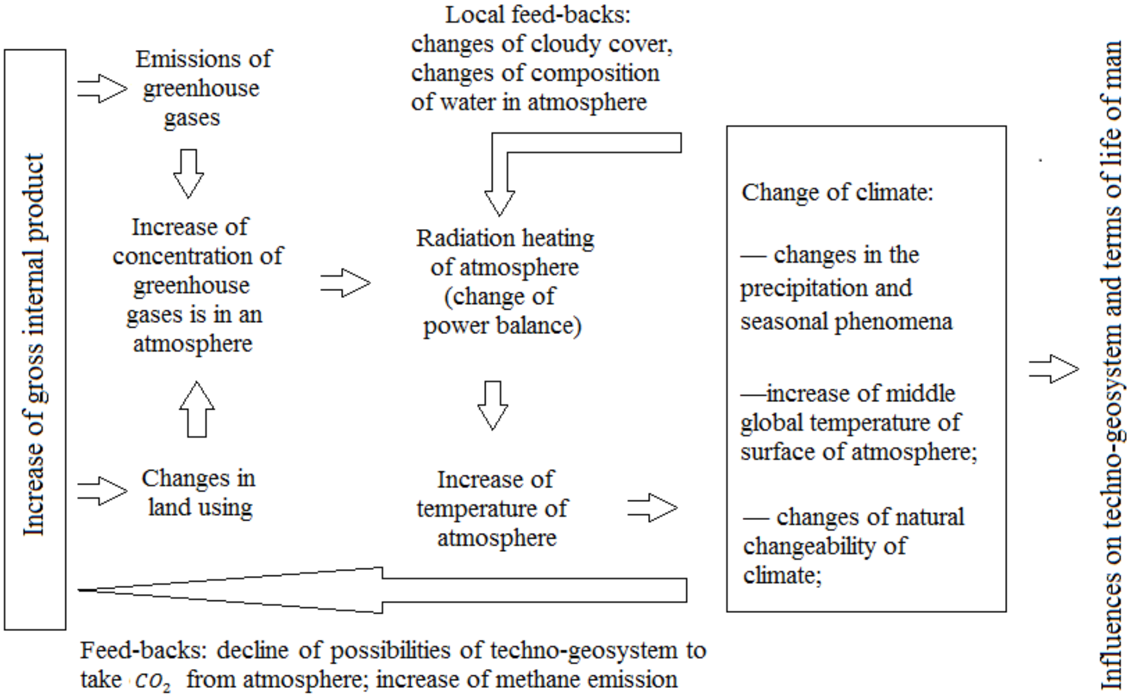


**Fig. 1 Chart of influence of the anthropogenic loading on the change of climate**

The research aim is to obtain a cartographic model of an urbanized territory by means of the thermal survey in an infra-red range. We use the obtained model for the exposure of proof thermal anomalies and thermal structures of the locality. We search connections between these thermal structures and natural and anthropogenic systems. We try to find zones in the urbanized territories that differ in the level of superficial heat.

The enterprises – the Zaporizhzhya Nuclear Power Plant and thermal power-station are the largest in the city of Energodar. In the city of Nikopol, there are Nikopol Plant of Ferro-alloys and a number of machine-building enterprises. The basic ecological problems of these cities consist in high levels of contamination of air, soils, complete or partial degradation of the ground surface, deterioration of the health status of the population, and other.

## 3 EXPERIMENTAL PART

Images taken in different seasons (thermal infrared channel, 11, 2010 year) were selected. The Landsat 8 satellite with sensors OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) with a resolution of 100 m were used as input data. The initial data of this research are satellite images of high resolution. These images were taken from the Landsat 8 satellite of the GeoTIFF format (Fig.2).

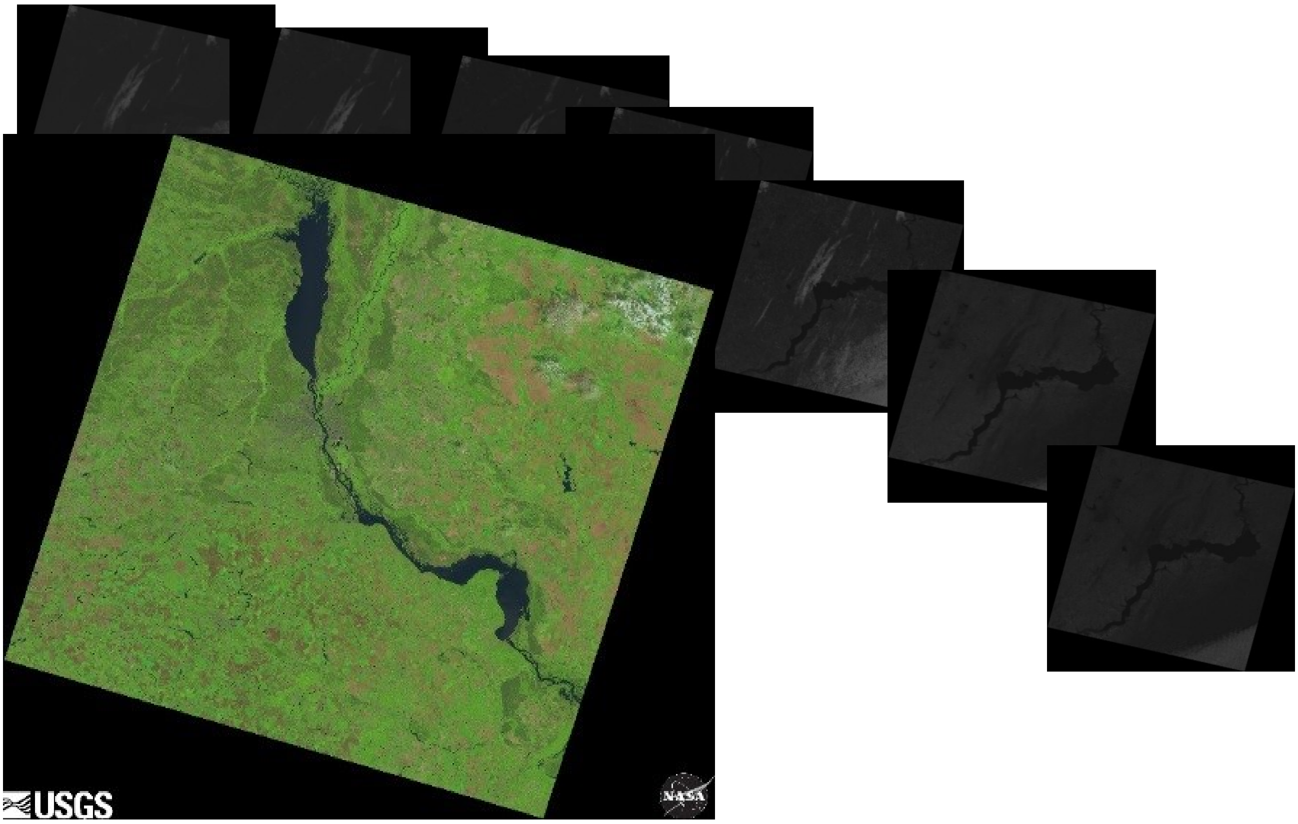


**Fig. 2 Satellite images of high resolution taken from the Landsat 8 satellite of the GeoTIFF format (https://libra.developmentseed.org)**

The images analysis was performed using the ArcGIS 10.2 software. Using the values of thermal channels (Table 1), the radioluminous temperature of the underlying surface of urban area can be determined [5]. Theoretically, the accuracy of the temperature is about 0.5°C; however, the haze in the atmosphere lowers the value by a few degrees.

**Tab. 1 Correspondence between the ranges of electromagnetic radiation and different channel numbers of Landsat satellites**

| The range | Landsat 1 | Landsat 2 | Landsat 3 | Landsat 4 | Landsat 5 | Landsat 7 | Landsat 8 |
|---|---|---|---|---|---|---|---|
| RED | 5 | 5 | 5 | 3 | 3 | 3 | 4 |
| NIR | 6 | 6 | 6 | 4 | 4 | 4 | 5 |
| Thermal | – | – | 8 | 6 | 6 | 61. 62 | 10. 11 |

The intensity of radiation R is the initial data for determining the temperature value, which came to the satellite sensor and is registered under a thermal channel. The intensity of radiation R is defined as (1):

$$R = M_R \cdot Q + A_R , \qquad (1)$$

where:

$M_R$, $A_R$ — calibration factors that can be found in the metadata file called "*_mtl.txt",

$Q$ — discrete calibration pixel value.

The temperature for the Landsat 8 satellite is defined according to the formula (2):

$$T = \frac{K_2}{ln\left(\frac{K_1}{R}+1\right)} - 273.15 \quad , \qquad (2)$$

where the values of constants $K_1$ and $K_2$ are obtained according to the thermal scene of each channel from its metadata file (Fig 3).

```
GROUP = TIRS_THERMAL_CONSTANTS
K1_CONSTANT_BAND_10 = 774.89
K1_CONSTANT_BAND_11 = 480.89
K2_CONSTANT_BAND_10 = 1321.08
K2_CONSTANT_BAND_11 = 1201.14
END_GROUP = TIRS_THERMAL_CONSTANTS
```

**Fig. 3 Metadata scenes of Landsat 8: calibration constants for calculating the surface temperature in urban areas**

In the Map Algebra point of Spatial Analyst tools, we use the Raster Calculator utility. The expression (1) is written in the corresponding field Raster Calculator. In doing so, we use the corresponding constants shown in Fig. 3. Figure 4 shows the use of the Raster Calculator utility in the ArcGIS 10.2 software.

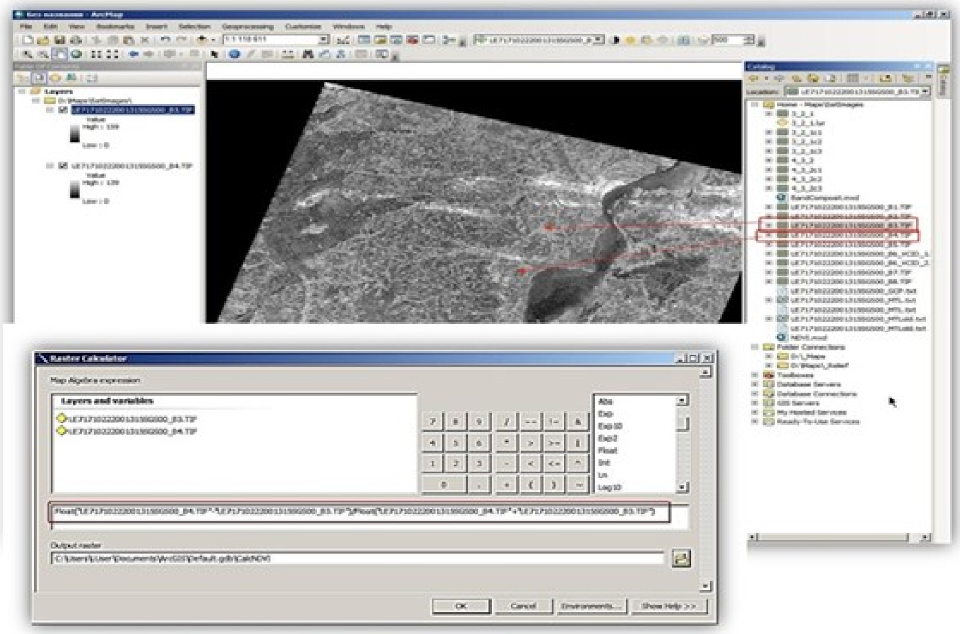

Fig. 4 **Use of the Raster Calculator for calculating the expression (1)**

## 4 RESULTS AND DISCUSSION

To analyse the temperature of the underlying surface, we used the data of the March 2013 heat channel. At this time, the urban area was already well warmed by the warm spring sun, while outside the city there was still a cold ground.

The clustering method of selected thermal images allowed revealing the structure of the thermal fields of the Energodar and Nikopol cities. This way, we determined the correspondence of objects to the natural or anthropogenic elements of the urban geosystem. Based on this clustering, we performed mapping of the thermal structure and thermal anomalies of the terrain. The thermal anomalies detection is associated with the real high intensity of heat emissions (industrial facilities).

The samples of results for determining the su rface temperature in the urban areas for the cities of Energodar and Nikopol in this thermal channel are shown in Fig. 5 and Fig. 6. The model of the thermal structure of the Tokai city and the nuclear power plant there with the same name "Tokai" (Japan) is built for comparison (Fig. 7). The government of Japan provides two mains activities: stable supply of energy on the one hand, and, on the other hand, protecting the environment, in particular reducing greenhouse gas emissions after the accident at the Fukushima I Nuclear Power Plant in March, 2011. Figure 8 shows an example of the three-dimensional model of thermal anomaly of the Energodar city and the nuclear power plant there.

It should also be noted that currently the problem of urban heat islands in Ukraine is paid significantly less attention than abroad, which determines the relevance of such research in the future.

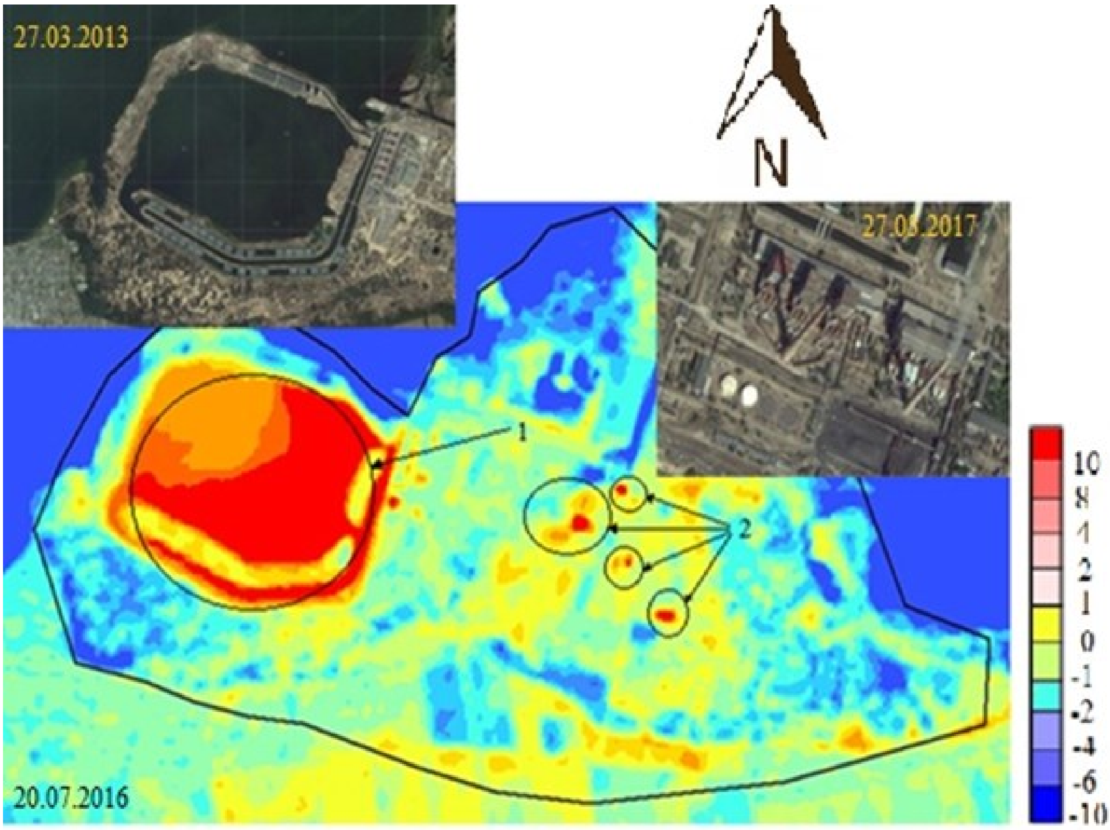


Fig. 5 **The thermal structure of the Energodar city: 1 – the thermal water pollution due to industrial water discharges from the nuclear power plant, 2 – the localized zones of thermal pollution, the source of which is industrial facilities of the thermal power station**

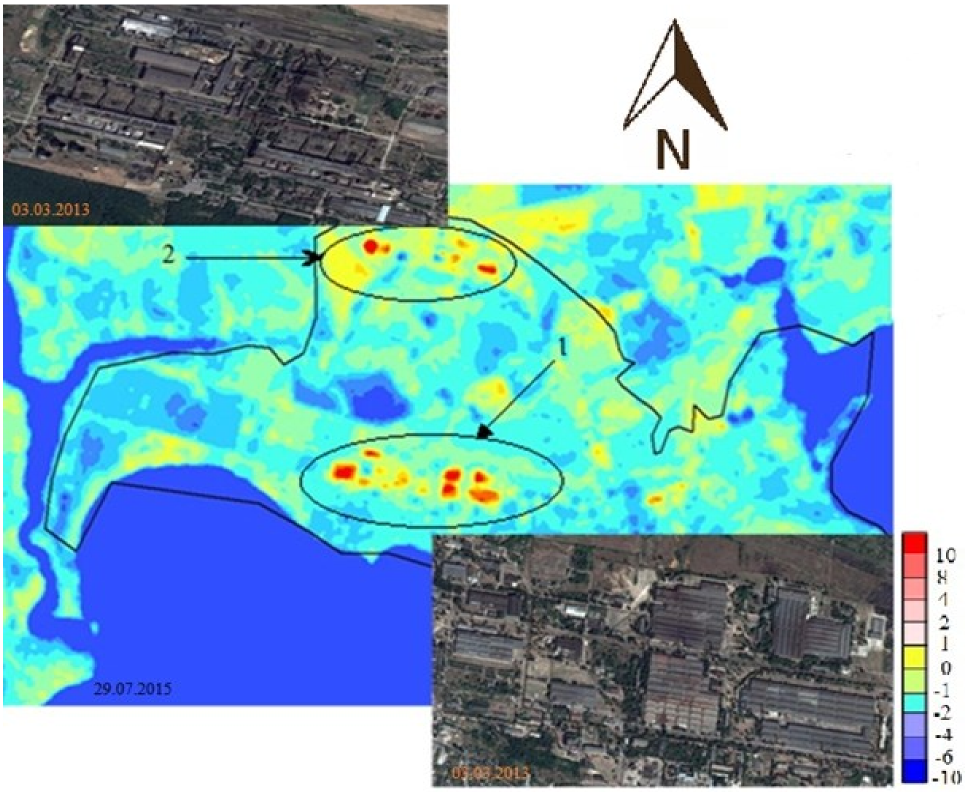


Fig. 6 **Thermal structure of the Nikopol city: 1 – thermal pollution from a steel pipes factory, 2 – pollution, the source of which is the Ferroalloy Plant**


**Fig. 7 Thermal structure of the Tokai city (Japan) and its nuclear plant**

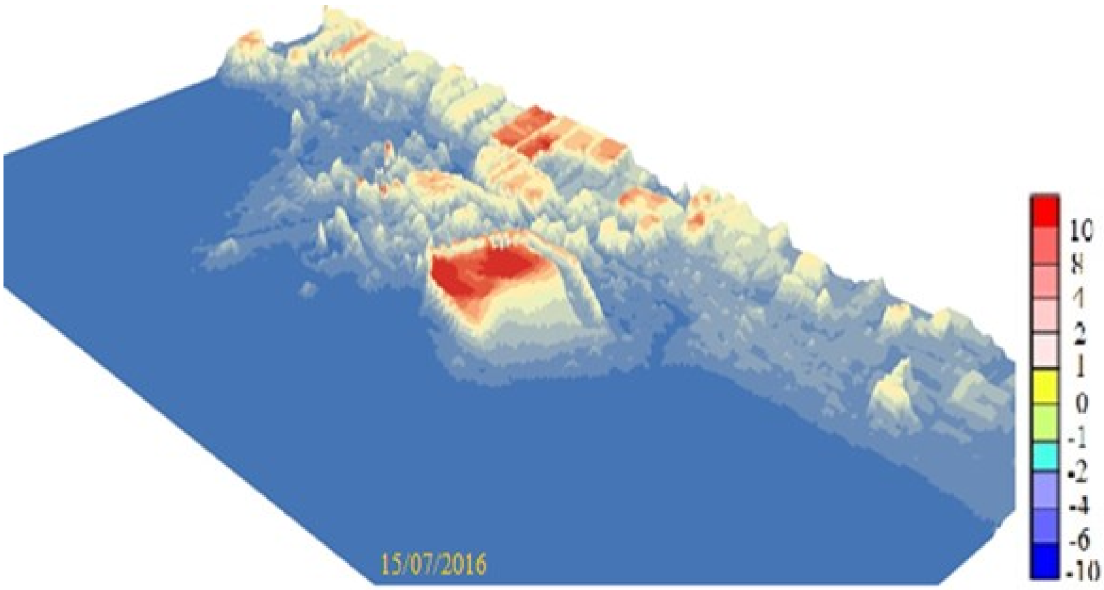


**Fig. 8 3D model of the thermal anomaly of the Energodar city and its nuclear plant**

## 5 CONCLUSIONS

Thus, there are the following conclusions:

1. The geoinformation models were established based on decoding the thermal data from satellite imagery. The models can distinguish objects that provide the major impact on the overall intensity of thermal emissions in the cities.

2. The geoinformation models of thermal anomalies indicate the presence of zones of ecological tension affecting natural and industrial structures of the city and comfortable dwellings of population in the urban environment. Large industrial enterprises are objects that increase the level of intensity of the thermal field in techno-geosystem.

3. The determination of thermal anomalies can be used as one of the elements for developing new forecasting and sustainable low carbon level direction of the urban environment by using renewable energy resources in the context of regional planning and design.

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